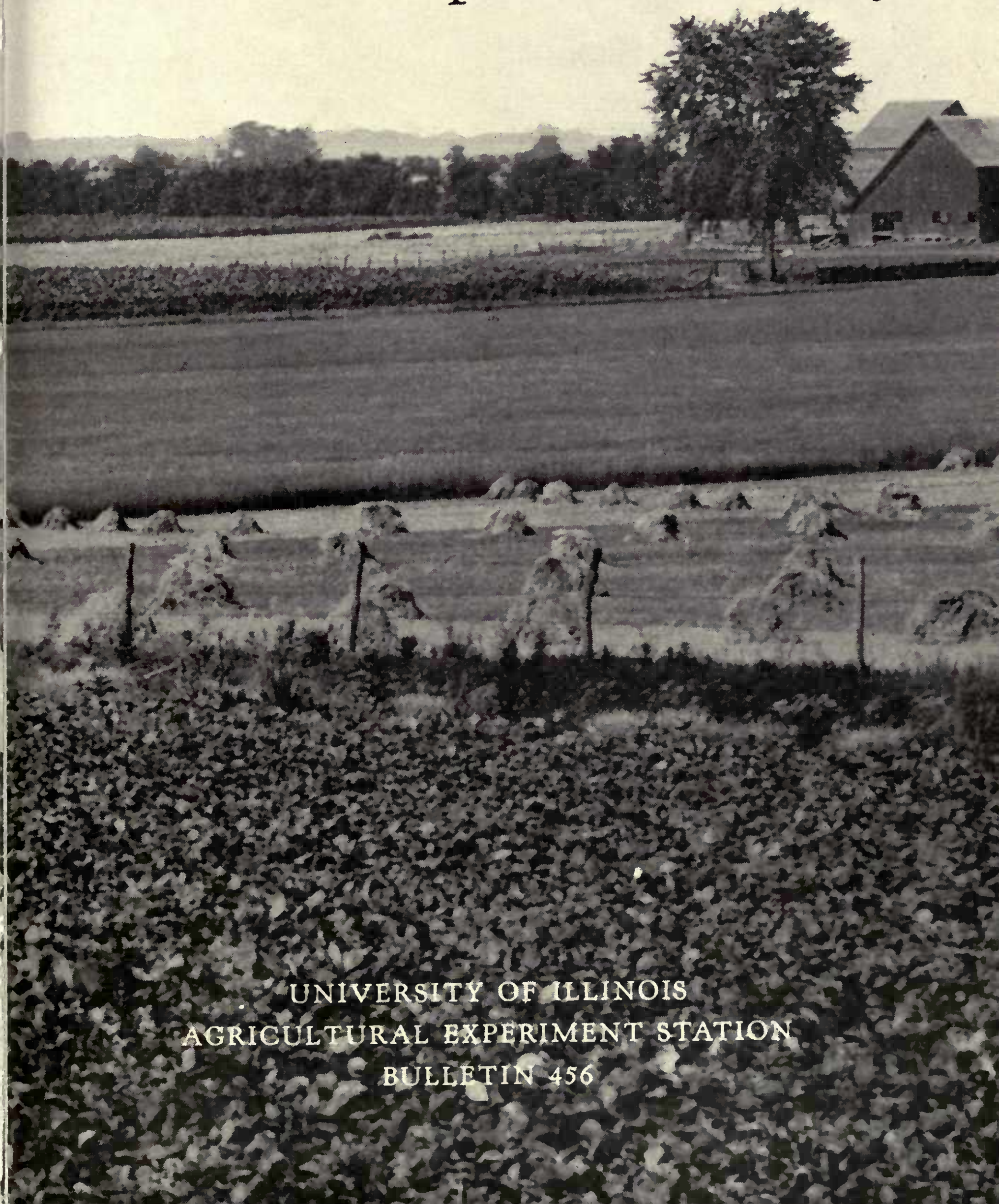
SOYBEANS
—their effect on soil productivity



UNIVERSITY OF ILLINOIS
AGRICULTURAL EXPERIMENT STATION
BULLETIN 456

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Urbana, Illinois June, 1939

Publications in the Bulletin series report the results of investigations made by or sponsored by the Experiment Station

Soybeans: Their Effect on Soil Productivity

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THE RAPID expansion of soybean acreage in Illinois during the past decade has brought to the fore the question of the effect of soybeans on the soil. Should soybeans, since they are legumes, be classified as a soil-improving crop? Or do they take from the land more plant-food materials than they return? Probably no other questions in soil management arouse more conflict of opinion among farmers than these. Opinions range from the belief that soybeans are one of the most effective soil-improving crops, to the extreme opposite view that they will ruin the land.

One reason for such difference in opinion is that many of the views are based on only a part of the evidence. For example, many are concerned only with the balance between removal of plant-food elements by the harvested crop and return of such elements in crop residues or manures; others are concerned only with the effect of soybeans on erosion. But the total effect of any crop on the soil is actually much more complicated than that, and can be assessed only when all the factors concerned are taken into consideration. In this bulletin the effect of soybeans on the soil is discussed from the standpoint of the use to which the crop is put—whether for hay to be fed on the farm, hay to be sold, grain to be sold and the straw returned to the land, or for green manure. The effects of soybeans, used in these ways, on soil tilth and tendency toward erosion, on the activity of soil bacteria, on the plant-food balance in the soil, and on the other crops in the rotation are presented. The discussion is based for the most part on experiments conducted at the Illinois Agricultural Experiment Station, tho data obtained at other Stations also are introduced as additional evidence.

Interest in this question of the effect of soybeans on soil productivity has run high in Illinois because soybeans have become the most popular legume grown in the state. In three of the four years from 1935 to 1938 soybeans were grown on more than 2 million acres in Illinois—more than the total of all other principal legumes combined.[1]

[1]Alfalfa, during the period 1934-1937, averaged 418,000 acres; sweet clover, 896,000 acres; and alsike, red, and mammoth clover, 319,000 acres.

Fig. 1.—A deep root system is characteristic of the soybean plant

Altho the roots constitute only about 10 percent of the soybean plant, they often extend into the soil to a depth of 4 or 5 feet. This deep-rooting characteristic is responsible in part for the great resistance to drouth offered by soybeans.

For several reasons this popularity of soybeans, and consequently the interest in their effect on the soil, is likely to continue. Some of these reasons are: *(1)* Supported by the many industrial uses discovered for soybean products, soybeans as a cash crop have brought larger money returns than some other crops in the rotation, particularly oats. *(2)* Soybeans make a good legume hay, high in protein and mineral elements. *(3)* They yield fairly well on soils too acid or too low in productivity to grow alfalfa or clovers successfully. *(4)* They are outstanding in drouth resistance, usually doing well wherever a good seedbed can be prepared, even in seasons too dry for seedings of alfalfa or clover to survive. *(5)* Like other legumes, they can obtain from the air a large proportion of the nitrogen they require, provided they are well nodulated. *(6)* They grow rapidly, are annuals, and therefore may be used as emergency hay or grain crops in late wet springs or at times when clovers and alfalfa have failed. *(7)* They are resistant to chinch bugs. *(8)* They serve well as a pasture crop, seeded either alone or in combination with other crops.

These are some of the favorable qualities which account for the widespread adoption of soybeans in Illinois; but if soybeans are to be fitted most usefully into Illinois cropping systems, their limitations also must be recognized. In this bulletin both the favorable and the unfavorable aspects of soybeans in relation to the soil are discussed.

EFFECT OF SOYBEANS ON SOIL TILTH

SOYBEAN LAND WORKS WELL

Farmers and investigators alike recognize a marked tendency of soybeans to improve the tilth of the soil. Land upon which a crop of soybeans has just been grown usually "works" well and is easily put in good shape for seeding of other crops (pages 556, 565). To be sure, this tendency to improve the soil tilth is not peculiar to soybeans, for most legumes and a few nonlegumes improve the soil structure; but it is more apparent with soybeans than with most of the others.

SOYBEAN LAND ERODES EASILY

The improvement in soil tilth, however, sometimes creates further problems in soil management, particularly in rolling fields. The loosening of the soil by the soybeans, coupled with the fact that practically the entire plant is removed from the land by harvest (Fig. 1), causes the soil to erode easily. This fact is clearly brought out in data obtained by Miller[5*] at the Missouri Agricultural Experiment Station and presented in Fig. 2.

Miller's data were obtained on a slope of 3.68 percent, with corn and soybeans planted in rows up and down the slope. The soybeans were drilled at cornplanter width in one case and solid (that is, in 8-inch rows) in the other. Rye was seeded as a winter cover crop after the soybeans, but not after the corn.

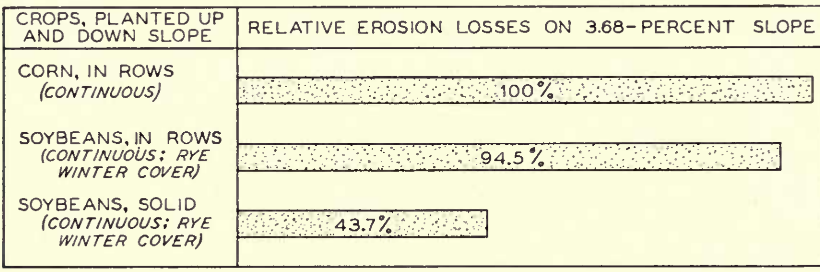

Fig. 2.—Relative erosion losses where corn and soybeans were planted up and down a moderate slope

Where the beans were drilled solid in rows of grain-drill width, erosion was less than half what it was where the beans were planted in rows of cornplanter width. Drilling the beans solid across the slope would reduce erosion still further. If the beans planted in rows of cornplanter width had not been followed with the rye cover crop, erosion would probably have been greater than it was where the corn was grown. *(Data from Missouri Agricultural Experiment Station[5*])*

Erosion on the soybean land was much reduced by planting the beans solid. Where they were drilled in cornplanter-width rows the erosion was about 94.5 percent as great as where corn was grown, but where they were drilled solid it was only 43.7 percent as great as where the corn was grown. Tho there were no direct data on erosion with beans drilled in 24- or 28-inch rows (much more extensively used for beans in Illinois than cornplanter width[a]), the erosion losses at these widths would be between the two given.

No data on erosion losses with soybeans seeded across the slope are included in the report of these experiments of the Missouri Agricultural Experiment Station. According to common experience with soybeans, however, as well as data obtained on other crops, drilling across the slope reduces still further the losses of soil from erosion on land

*These numbers refer to literature citations on page 571.
[a]Ill. Agr. Exp. Sta. Bul. 428, p. 362.

growing soybeans. For example, at the Clarinda Soil Conservation Experiment Station[6*] land growing listed corn in rows up and down the slope lost 13.27 tons of soil per acre per year, whereas where the corn was listed on the contour there were no erosion losses.

Thus, if erosion on rolling soybean land is to be avoided, the beans should be drilled solid, and across the slope—that is, on the contour. When beans are drilled solid, however, the problem of controlling

Fig. 3.—On land subject to erosion soybeans should be seeded on the contour

Drilling soybeans solid gives more effective erosion control but less effective weed control than drilling them in rows, as shown here. *(Courtesy U. S. Soil Conservation Service)*

weeds of course becomes more difficult; consequently it is imperative that precaution be taken to kill as many weeds as possible before and shortly after seeding—by the judicious use of the rotary hoe or harrow at the appropriate time.

When soybeans are combined, the threshed straw has a tendency to lessen erosion, particularly where the beans are combined on the contour. If, however, the combine is run up and down the slope, gullies may start where the wheels cut into the soil, particularly if the straw is left in windrows, and so erosion may be increased rather than decreased.

FALL-PLOWED SOYBEAN LAND "RUNS TOGETHER"

Another difficulty arising from the fact that the land is in good tilth following a soybean crop, is the tendency of fall-plowed soybean land to "run together" badly after the winter and spring rains. Such land is more difficult to prepare in the spring than if it were spring-plowed.

The reasons why the fall-plowed soybean land runs together so badly are not yet, perhaps, completely understood. Some farmers have raised the question whether the poor working condition of the soil in the spring after the fall-plowing of soybean land might not be due to a destruction of nodule bacteria by freezing. There is no evidence to indicate any such effect. Some nodule bacteria undoubtedly are killed by freezing, but a large percentage survive. Even if all were killed, however, such a situation could not give rise to a poor physical condition of the soil.

Probably the main reason for this difficulty is that the soybean land is so easily pulverized by plowing that the fall and winter rains cause it to "run together." In contrast, sodland is not so easily pulverized by fall plowing; the land remains rough, and consequently it has less tendency to become compacted by the winter rains.

EFFECT ON SOIL PRODUCTIVITY

NITROGEN ADDITIONS DEPEND ON CROP USE

With good nodulation resulting from efficient nodule bacteria, soybeans obtain nitrogen from the air; but even where good nodulation and high nitrogen fixation are obtained, the effect of soybeans on the nitrogen balance in the soil is determined by the use that is made of the crop. Under the best conditions soybeans can obtain about two-thirds of their nitrogen from the air; the other one-third must be obtained from the soil itself. Furthermore, the soybean plant has a comparatively small root system, about nine-tenths of the plant being above ground. The amount of nitrogen contained in the tops is therefore greater than the amount secured from the air; and consequently when all the above-ground parts of the plant are harvested from the land, no nitrogen is added to the soil by the soybeans.

The amounts of nitrogen added to or removed from the soil by soybeans when the crop is used in different ways are shown in Fig. 4. The data are based on a yield of 20 bushels of seed or 4,500 pounds of hay or green manure per acre. The nitrogen additions indicated do not, of course, take leaching into consideration. In any estimate of the practical effect of soybeans on the nitrogen balance in the soil, however, the effect of leaching must not be overlooked. Unless a fall-seeded crop follows the soybeans, the losses of nitrogen by leaching may be greater than the amounts added by the soybeans, except when soybeans are used as a green-manure crop.

Plowing under well-nodulated soybeans as green manure adds considerable nitrogen to the land. But the amount added depends, of course, both upon the yield of the crop and upon the proportion of the total nitrogen in the plants that has been secured from the air.

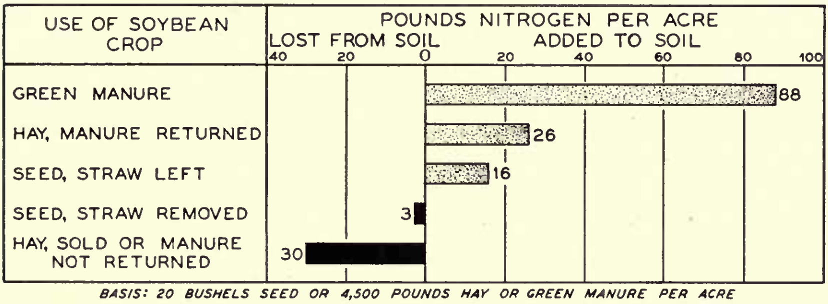

Fig. 4.—Nitrogen additions and losses where soybean crops are used in different ways

Unless the tops, or a part of them, are returned to the soil either as straw or as green or livestock manure, the growing of soybeans will lower the nitrogen supply in the soil. *(Figures are averages of data compiled from many sources.)*

Where soybeans are harvested with a combine-thresher and the straw is left in the field, less nitrogen is taken from the land by the removal of the seed than is secured from the atmosphere, and there is an apparent addition of 16 pounds of nitrogen per acre. Too much emphasis must not be placed on the value of this addition, however, because, unless a fall-seeded crop follows the soybeans, all the nitrogen added may be leached away before a spring crop is planted.

Where the seed is harvested and the straw is not returned, or where the manure obtained when the soybeans are fed is not carefully utilized, there will be a loss of nitrogen from the soil. Whether or not the use of soybeans for hay adds to or subtracts from the nitrogen of the soil depends upon the way the manure is handled.

Comparisons with other crops. These relationships are not peculiar to soybeans. The soil-improving value of any crop depends on how it is used. Even alfalfa, which is rated high as a soil-improving crop, adds little if any nitrogen to the soil where it is cut for hay and the hay is sold.

In an analysis of the tops and roots of alfalfa at the University of Illinois,[2*] three cuttings of alfalfa yielding 4¼ tons per acre contained 232 pounds of nitrogen, whereas the roots contained only 68 pounds of nitrogen. Assuming that two-thirds of the nitrogen was obtained from the air, the amount of nitrogen taken off in the hay was larger than the amount obtained from the air. This loss of nitrogen was approximately balanced, however, by the return of the fall growth containing 42 pounds of nitrogen per acre. Thus where no livestock manure was returned to the soil, there was no gain in the nitrogen content of the soil from the growing of alfalfa. Swanson and Latshaw[8*] in Kansas also have shown that no nitrogen is added when alfalfa is removed from the land.

TABLE 1.—PLANT-FOOD ELEMENTS ADDED OR REMOVED BY VARIOUS CROPS
(Data compiled from various sources)

Crop	Acre-yield	Nutrient elements per acre					
		Added N	Removed				
			N	P	K	Ca	Mg
		lb.	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*
Corn	40 bu.	..	40	7	8	.4	2.8
Oats	40 bu.	..	26	4.5	6.5	.8	1.6
Wheat	25 bu.	..	36	6	7.5	.5	2
Soybeans[a]	20 bu.	16	..	8	25	2.8	3
Soybeans[b]	2¼ tons	..	30	13	40	72	31
Alfalfa[b]	3 tons	..	..	13	96	120	24
Red clover[b]	2 tons	..	..	10	60	64	18

[a]Soybeans sold, straw returned. [b]Hay sold, no manure returned.

Because a smaller proportion of the soybean plant than of the alfalfa plant consists of roots, and because soybeans make no fall growth to replace the loss incurred when the tops are removed, it is even more important in building up the nitrogen balance in the soil with soybeans, than when building it with alfalfa, to return a substantial portion of the tops to the soil either as green manure or as livestock manure.

The effect of corn and other grains and legumes on the nitrogen balance of the soil is shown in Table 1, along with data on soybeans. It is to be noted that whereas a 40-bushel crop of corn removes 40 pounds of nitrogen an acre, and a 25-bushel crop of wheat takes 36 pounds an acre, by none of the methods of handling a 20-bushel crop of soybeans is there removed more than 30 pounds of nitrogen an acre.

Nitrogen excretions from roots. A mere analysis of a leguminous plant probably does not give the complete picture of the nitrogen-fixing ability of that plant. Virtanen[9*] has shown that under some conditions nitrogen excretions take place from the roots. An analysis of the plant, even tho it includes both roots and tops, does not include these excretions. It is possible, therefore, that all the figures cited in the foregoing paragraphs for nitrogen additions are somewhat too small, and that those for nitrogen removal are too large. Just how much the figures should be modified in order to compensate for excretions, however, it is impossible to state.

SOYBEANS DRAW HEAVILY ON MINERALS

Consideration of the effect of soybeans upon soil productivity must include the effect upon mineral elements as well as upon nitrogen. The extent to which four elements are removed by soybeans and by five other important corn-belt crops is shown in Table 1.

A 20-bushel crop of beans sold as seed, with the straw returned to the soil, removes slightly more phosphorus than a 40-bushel crop of corn where the grain is sold and the stalks returned to the soil, and it removes more than three times as much potassium. The beans also remove more calcium and magnesium than the corn. If the bean crop is sold for hay, twice as much phosphorus and five times as much potassium are removed by 2¼ tons of hay as are removed by 40 bushels of corn. Alfalfa also draws heavily on minerals. A three-ton crop of alfalfa takes from the soil twice as much phosphorus and 12 times as much potassium as a 40-bushel crop of corn. Thus when soybeans are compared with corn, the loss of mineral elements from the soil appears large, but when compared with alfalfa the removals do not seem so great.

So it is that the removal of plant-food elements from the soil by the soybean plant may seem great or small, depending upon the yardstick by which it is measured. It is certain, however, that the continued growing of large crops of soybeans for market purposes will gradually but surely deplete the soil of those mineral elements in which it is rich—just as will the growing of any other crop for a similar purpose. If profitable yields are to be maintained, it will become necessary sooner or later, depending upon the characteristics of the individual soil, to return to the land the phosphate, potash, and lime taken off by the crops.

SOYBEANS AFFECT BIOLOGICAL ACTIVITY

A third factor of importance in evaluating the effect of a crop on the productivity of the soil is its influence on soil microorganisms. Experiments at Urbana, where a rotation of soybeans, corn, corn, corn has been carried on for thirty-six years under both livestock and grain systems of farming, throw light on this question with respect to soybeans. On all plots either manure or crop residues have been returned to the soil, and in addition some of the plots have received applications of rock phosphate.

Microorganic population increased. The average yields of corn during the first, the second, and the third year after soybeans over the 36-year period are given in Table 2, and counts of microorganic population of the soil during the year 1928 are given in Table 3.[7*]

Under each soil treatment the average number of microorganisms was highest during the first year after soybeans and became lower during each succeeding year. Thus on soil receiving crop residues and rock phosphate, 15.1 million microorganisms per gram of soil were counted the first year after soybeans, 12 million the second year, and 10.2 million the third year. The decrease from year to year was observed in all plots regardless of soil treatment. All the differences were statistically significant, having odds ranging from 1666:1 to 59:1.

Undoubtedly several factors were responsible for these differences. Only two, however, are taken up here—the improvement of soil tilth and the increase in available nitrogen in the soil after soybeans. As stated on page 549, soil where soybeans have been grown is in much better physical condition than where corn has been grown. In the rotation under consideration this fact is very apparent when the land is being prepared for corn. The first year after a soybean crop has been

TABLE 2.—CORN YIELDS IN A SOYBEAN-CORN-CORN-CORN ROTATION ON SOILS RECEIVING DIFFERENT FERTILIZER TREATMENTS, URBANA
(Averages for 36 years, 1903-1938)

Year after soybeans	Yields from plots treated with—				Average, all treatments
	R	RrP	M	MrP	
	bu.	*bu.*	*bu.*	*bu.*	*bu.*
First	46.5	50.8	51.6	53.8	50.7
Second	42.7	45.3	47.6	49.7	46.3
Third	39.6	43.2	41.5	44.8	42.3

R = crop residues—cornstalks and threshed bean straw. M = livestock manure—one ton for each ton of crops grown. rP = rock phosphate.

grown the land pulverizes easily and a good seedbed is prepared with little difficulty; whereas in the third year after soybeans, the land is cloddy and a good seedbed is difficult to prepare. The improvement in physical condition is, without doubt, favorable to the development of microorganisms, particularly those requiring plenty of oxygen.

TABLE 3.—MICROORGANISMS PER GRAM OF AIR-DRY SOIL IN A SOYBEAN-CORN-CORN-CORN ROTATION UNDER DIFFERENT FERTILIZER TREATMENTS, URBANA, 1928

Year after soybeans	Millions of microorganisms per gram of air-dry soil from plots treated with—				Average, all treatments
	R	RrP	M	MrP	
First	12.6	15.1	14.7	15.5	14.5
Second	9.1	12.0	10.4	13.4	11.2
Third	8.2	10.2	8.6	10.9	9.5

R = crop residues—cornstalks and threshed bean straw. M = livestock manure—one ton for each ton of crops grown. rP = rock phosphate.

The second factor accounting for the large number of soil microorganisms immediately after the soybean crop is the effect of soybeans on the quality of the organic matter of the soil. Microorganisms quickly respond to additions of nitrogenous organic matter to the soil. Because the soybean crop is relatively high in nitrogen, the return of any part of the crop to the land has a direct effect upon the activity of soil microorganisms. On all the plots where soybeans were grown, the roots remained; and on the residue plots the straw was returned. These residues thus no doubt were partly responsible for the increase in the number of soil microorganisms.

The high correlation between numbers of microorganisms and yield of corn is particularly interesting. The highest yields occurred on plots having the highest microorganic population, and vice versa. Either the same factors which are responsible for high corn yields are responsible for large numbers of organisms, or the large number of microorganisms increase the productivity of the soil. There is good reason to believe the latter situation obtains in this case.

Nitrate nitrogen higher the first year after soybeans. One of the functions of soil microorganisms is the production of nitrate nitrogen from the organic matter of the soil, and it is a well-known fact that a deficiency of nitrate nitrogen limits crop yields on many soils. Consequently the nitrate-nitrogen accumulation was examined in the soil where the rotation of soybeans and three years of corn was followed at Urbana. The average number of pounds of nitrate nitrogen per acre (averages of analyses on nine different dates) is shown in Table 4.

Although the nitrate-nitrogen content fluctuates considerably thruout the season as a result of nitrate production, nitrate utilization by the corn crop, and climatic and seasonal effects, it is clear from these data that nitrate-nitrogen accumulation, corn yields, and the place in the rotation occupied by the corn,—all are closely related. In the first year after soybeans the average nitrate-nitrogen content (average of analyses at different times and on plots where different soil treatments were used) was 27.7 pounds an acre. During the second and third years after soybeans the averages were 16.4 and 13.3 pounds respectively.

TABLE 4.—NITRATE NITROGEN PER ACRE IN SOIL IN A SOYBEAN-CORN-CORN-CORN ROTATION, UNDER DIFFERENT FERTILIZER TREATMENTS, URBANA, 1928

Year after soybeans	Pounds of nitrate nitrogen per acre in soil of plots treated with—				Average, all treatments
	R	RrP	M	MrP	
First	21.6	30.2	29.2	29.8	27.7
Second	17.8	13.4	14.5	19.8	16.4
Third	11.7	13.4	13.1	15.1	13.3

R = crop residues—cornstalks and threshed bean straw. M = livestock manure—one ton for each ton of crops grown. rP = rock phosphate.

Nitrifying efficiency increased. In a laboratory experiment[7*] on the nitrifying efficiency of soils during the first, second, and third years after soybeans, the soybean crop was shown to have more effect upon nitrate-nitrogen accumulation than would be accounted for by the mere addition of nitrifiable organic matter to the soil (Fig. 5).

In this experiment soil from the field was reinforced with $(NH_4)_2SO_4$ at the rate of 10 milligrams of nitrogen per 100 grams of soil and with dried blood at the rate of 250 milligrams per 100 grams of soil. The soil was maintained at a uniform optimum moisture content and analyzed for nitrate nitrogen at the end of 20 days. The soil growing corn the first year after soybeans had, in addition to a higher initial nitrate-nitrogen content, a higher nitrifying efficiency than the soil growing the third crop of corn after soybeans.

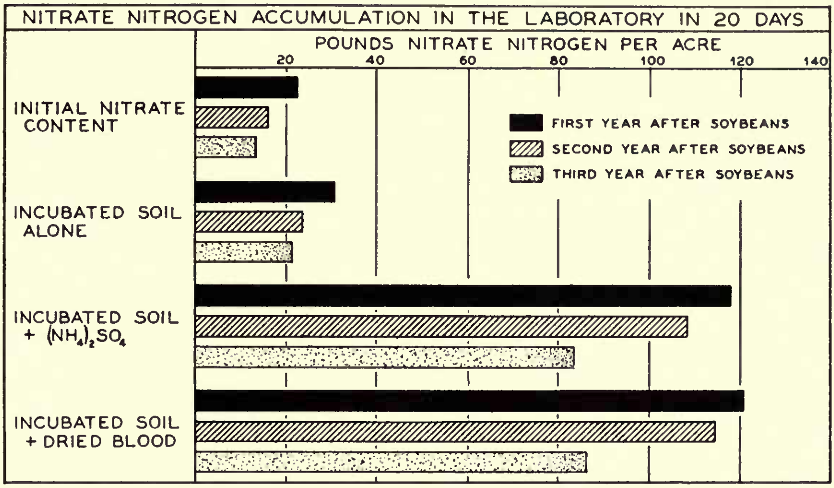

Fig. 5.—Nitrate-nitrogen accumulation in soil in laboratory tests during first, second, and third years after soybeans

Accumulation of nitrate nitrogen was highest and most rapid during the first year after soybeans. (On half of the plots tested, soybeans were cut for hay and livestock manure was returned to the soil; and on the other half, soybeans were cut for seed and soybean straw was returned.)

PLACE OF SOYBEANS IN THE ROTATION

It should now be clear that in any consideration of the relation of soybeans to other crops in the rotation, the effects of the soybeans on the physical, chemical, and biological nature of the soil should be taken into account. It would be just as erroneous to conclude that soybeans have a purely beneficial effect on the soil as it would be to conclude that they are entirely detrimental. Neither the unfavorable nor the favorable effects should be lost sight of. Under certain conditions soybeans contribute to soil erosion; but at the same time they have a favorable influence on microorganic population, nitrate accumulation, and nitrifying efficiency. On the whole, judged by the data presented here, they have a favorable influence upon yields of corn when corn follows them in the rotation.

Aside from considerations of labor distribution and cash returns from the crop—problems which are not within the scope of this bulletin—the frequency and place of soybeans in a rotation must be determined by the topography and productiveness of the soil, the disposition to be made of the crop, and the physical, chemical and biological responses which may be expected in the soil.

SOYBEANS AS A GREEN-MANURE CROP

When well-nodulated soybeans are plowed under as a green-manure crop, additions of nitrogen may range from 60 to 100 pounds an acre, depending on the productivity of the soil. A 2¼-ton green-manure crop of soybeans (dry basis) has been calculated to add to the soil 88 pounds of nitrogen an acre (page 553). While not adding any minerals to the soil, soybeans so used do actually increase the supply of available

Fig. 6.—Soybeans are a good but an expensive green manure

A heavy crop of soybeans plowed under as green manure will add from 60 to 100 pounds of nitrogen an acre. Because of their expense, however, soybeans are not usually so practical a green-manure crop as sweet clover or alfalfa.

mineral nutrients. This is brought about by the fact that in the growing process they assimilate, and therefore remove, considerable quantities of these minerals from the soil solution; and in this removal conditions are created that cause part of the temporarily unavailable supply of mineral nutrients to become more readily available. So when the crop is returned to the soil as a green manure, the soil has the benefit of the assimilated minerals plus the further quantities that have been converted into available form. This increase in the supply of available mineral nutrients is of course at the expense of the less readily available supply, and this fact must be taken into consideration in any long-time view of fertility problems.

The immediate effect of a soybean green-manure crop on the yield of the succeeding crop is determined by such factors as the size and composition of the soybean crop, the kind of crop that follows it, and seasonal conditions.

Response of succeeding corn and wheat crops. Corn, because it is able to utilize nitrogen more effectively than small-grain crops, is ordinarily, tho not always, preferred as the crop to follow soybeans when soybeans are used as a green manure. In tests conducted at the Arkansas Station, corn after oats yielded 34.6 bushels an acre, whereas corn following soybeans used as a green manure yielded 54.5 bushels an acre.[4*] Where soybeans were used as a catch crop after oats and then plowed under, the corn yield was 42 bushels an acre. Some Illinois farmers have obtained even greater increases than these after plowing under soybeans. For example, a difference of 30.7 bushels an acre between the yield of corn after soybeans had been plowed under as a green manure and the yield after soybeans had been cut for seed was reported from a well-controlled test in 1937.[a] It should be kept in mind, of course, that 1937 was a particularly favorable year for corn.

Wheat may satisfactorily follow soybeans used as a green manure on land not too high in productivity. If the soil is already sufficiently productive to supply considerable available nitrogen, the plowing under of the soybeans results in an excessive amount of nitrogen, which in turn causes wheat to lodge. Such was the case in the Illinois experiment on growing wheat after soybeans in 1937 (Table 6). At the Virginia Agricultural Experiment Station[11*] wheat after soybeans cut for hay yielded 4.3 bushels an acre more than the check, and wheat after soybeans plowed under yielded 11 bushels more than the check (Table 5). When the wheat followed the green-manure crop, yield of straw was increased more, relatively, than the yield of grain. This result is to be expected because increases in available nitrogen tend to stimulate production of straw in small-grain crops more than grain.

Soybeans an expensive green manure. Even tho soybeans used as a green manure have a highly favorable effect on yields of crops which follow, their use for this purpose is advisable only in exceptional

[a]Reported to the author in correspondence from T. H. Brock, Farm Adviser of Woodford county, November, 1937.

TABLE 5.—WHEAT YIELDS ON SOIL WHERE SOYBEANS HAD BEEN GROWN THE PRECEDING YEAR
(Data from Virginia Agricultural Experiment Station[11*])

Use of soybeans	Acre-yield of wheat	Weight of wheat grain per pound of straw
	bu.	*lb.*
No soybeans (check)	19.8	.65
Cut for hay	24.1	.66
Green manure	30.8	.57

cases. Considering cost of production,[a] benefits obtained, and adaptability to rotations, the deep-rooted legumes, such as sweet clover, are better adapted for soil-improvement purposes and soybeans better adapted for grain or hay. When the problem is to increase the productivity of soils that are too sour to grow sweet clover, it may be preferable to grow soybeans for grain and buy enough limestone to correct the soil so that sweet clover can be grown.

Should be plowed under late in fall. Where it seems feasible to use soybeans as a green-manure crop, the fact that they are high in nitrogen, and consequently decompose rapidly should be kept in mind. Under conditions favorable for decomposition a considerable portion of their nitrogen is converted into nitrates—a form that is utilized readily by plants and also one that is lost quickly thru drainage water. Consequently, unless a fall-seeded crop is to be sown, the soybeans should be plowed under as late as possible in the fall, when soil temperatures are low enough to slow down the microorganic activity responsible for the decay of the beans.

Because of the desirability of late plowing, the late-maturing varieties, which retain their leaves until frost, are more suitable for green manuring than the earlier varieties. Where the earlier varieties are used, late plowing still is advisable, even tho at the risk of losing some of the leaves by blowing.

On rolling land the plowing under of soybeans for green manure may even be delayed until spring, in order to reduce erosion. Where erosion is a serious problem, however, the growing of soybeans for green-manuring purposes is a questionable practice (page 549).

[a]Information on current costs of producing soybeans may be obtained from mimeographed reports issued by the Department of Agricultural Economics, University of Illinois. Costs during the period from 1928 to 1934 are covered in Illinois Bulletin 428, "Soybean Costs and Production Practices."

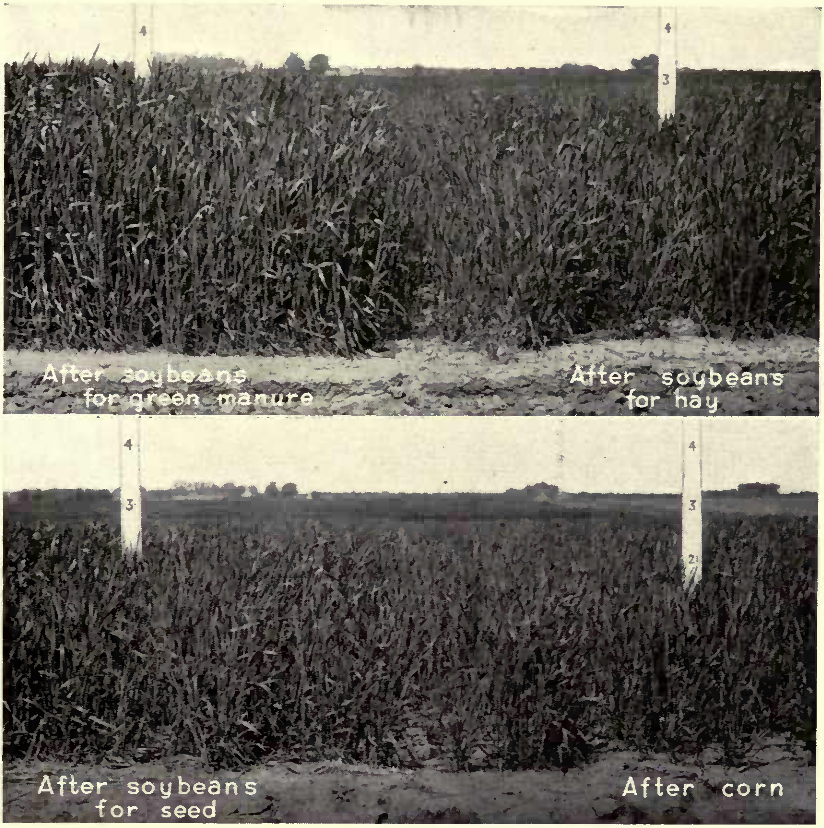

Fig. 7.—Wheat on good-quality soil, following soybeans used in different ways, and following corn

Regardless of the way in which the previous soybean crop was disposed of, wheat made more rapid growth following soybeans than following corn. Shortly after these pictures were taken the wheat on the plot where soybeans were plowed under for green manure lodged badly. *(Photographs taken late in May, 1939)*

WINTER GRAIN DESIRABLE AFTER SOYBEANS

Economy of labor, reduction of soil erosion, and conservation of soil nitrogen against leaching are good reasons for seeding winter grain after soybeans. If seeded across the slope, on the contour, a grain crop will lessen the rate of water run-off and consequently reduce erosion losses (Figs. 8 and 9). The growing crop also utilizes

Fig. 8.—Serious erosion occurs on rolling land when soybeans are not drilled on the contour and are not followed by a cover crop

Such damage as this can be largely prevented by drilling soybeans solid on the contour, harvesting them on the contour, and following them with a cover crop also drilled on the contour. *(Courtesy U. S. Soil Conservation Service)*

the available nitrogen as it accumulates, and thereby prevents, or at least decreases, the loss of nitrates by leaching.

WHEAT AFTER SOYBEANS MAY NEED FERTILIZER

Many farmers, altho they recognize these advantages for seeding winter grain crops after soybeans, have hesitated to follow this practice because frequently the yields of wheat following soybeans have seemed unsatisfactory. Observations at this Station and at other stations indicate at least three reasons for these occasional unfavorable results. These are that soybeans mature late for wheat seeding; soybean land is loose for a wheat seedbed; and available phosphorus is likely to be low.

Soybeans mature late for wheat seeding. In the first place, the highest yielding varieties of soybeans frequently do not mature sufficiently early to permit sowing wheat at the usual wheat-seeding date

Fig. 9.—A winter cover crop after soybeans helps to control erosion

A cover crop of small grain—wheat, rye, winter barley, or oats—particularly if seeded on the contour, furnishes needed protection after soybeans. Often the small grain can be seeded directly after the combine, with no further seedbed preparation. *(Courtesy U. S. Soil Conservation Service)*

and, as a result, the wheat does not make a good growth before winter weather begins. The use of an earlier variety of soybeans, even if somewhat lower in yielding ability, would tend to obviate this difficulty.

Soybean land "loose" for wheat seedbed. In the second place, soybeans leave the soil loose—probably too loose for the best yields of wheat. Tho there is little of a practical nature that can be done to compact the seedbed, it is possible to refrain from practices which will tend to further loosen the soil, such as plowing or disking. Consequently many farmers now drill wheat directly behind the combine without any seedbed preparation, permitting the threshed straw to fall uniformly on the land where the wheat has just been seeded.

Experimental evidence at this Station indicates that such a practice is feasible. Wheat seeded on land where no preparation was made after beans were harvested for seed, yielded 4 bushels an acre more than wheat seeded on soybean land where the seedbed was prepared by thoro disking and harrowing. On some soils this method might not work as successfully as it does on good corn-belt land.

Available phosphorus likely to be low. A third and more important reason why wheat is sometimes unsatisfactory after soybeans is that readily available plant nutrients, particularly phosphorus, may be deficient after the beans. Soybeans up to the time when they mature, which is also wheat-seeding time, draw heavily upon the supply of these nutrients. As a result, before the wheat begins to feed there is too little time for plant-food elements, in amounts sufficient for the wheat, to be formed from the temporarily unavailable portion of the soil by bacterial and other soil processes. Under such conditions, if satisfactory wheat yields are to be obtained it is important to supply additional plant nutrients.

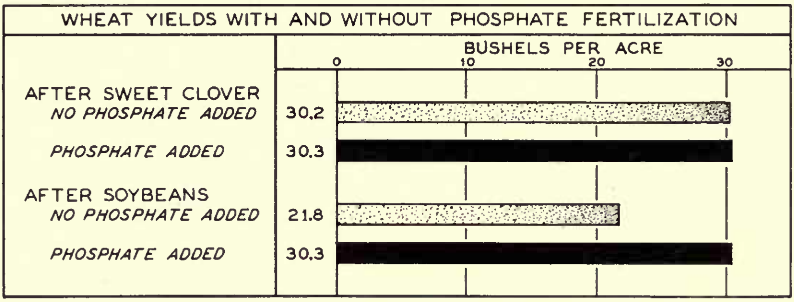

Fig. 10.—Wheat yields after soybeans were cut for seed, and after sweet clover was plowed under, with and without phosphate fertilization

Application of phosphate was definitely an advantage after the soybeans but not after the sweet clover.

This fact—that available phosphorus may be too low for wheat immediately following soybeans—was brought out in an experiment at the Illinois Station in which wheat was grown after sweet clover and after soybeans (Fig. 10). The sweet clover was plowed under in August and the soybeans were cut for seed. Superphosphate (20 percent P_2O_5) was broadcast at the rate of 300 pounds an acre and was harrowed into the soil.

The land that had grown sweet clover the preceding year gave no higher yields of wheat with phosphate fertilization than without; but soybean land to which phosphate was applied yielded 8.5 bushels more wheat per acre than soybean land to which no phosphate was added. These data are for one year only and consequently are subject to the limitations of any short-time experiment.

In another experiment, in 1937, the effect of a fertilizer containing phosphate on wheat yields was demonstrated again. The data are given in Table 6. In this experiment 150 pounds of a 2-12-6 fertilizer (containing 2 percent nitrogen, 12 percent P_2O_5, and 6 percent K_2O) was drilled in the row with a fertilizer attachment on the wheat drill. In every case the fertilized wheat yielded considerably more than the unfertilized. Without doubt the larger yield and the better quality of the fertilized wheat was due in part to its earlier maturity. Late-ripening wheat was damaged considerably by stem rust, whereas wheat that ripened early was not injured so greatly.

TABLE 6.—EFFECT OF FERTILIZATION OF SOIL AND USE MADE OF SOYBEAN CROP ON ACRE-YIELD OF WHEAT, URBANA, 1937

Use of soybeans	Yield of wheat when soil was—		Test weight per bushel of wheat when soil was—	
	Fertilized[a]	Not fertilized	Fertilized[a]	Not fertilized
	bu.	*bu.*	*lb.*	*lb.*
Seed	22.5	11.2	55	45
Hay	20.7	11.7	53	46
Green manure	17.9	15.1	45	43

[a]Fertilizer consisted of 2 percent nitrogen, 12 percent P_2O_5, and 6 percent K_2O.

The yield of wheat after the soybeans used as a green-manure crop was unexpectedly low, but this also was a result of rust damage. The large amount of available nitrogen produced from the decaying soybeans increased straw yield and delayed maturity at the expense of both yield and quality of grain. Even where the soil was fertilized with phosphorus, the test weight of the wheat was only 45 pounds a bushel. Where wheat was grown on fertilized soil after soybeans had been cut for seed or for hay, the wheat tested 55 and 53 pounds a bushel respectively.

Differences between the yields of wheat on the plots where soybeans had been cut for seed and where they had been used for hay were not significant. This was probably due to two factors which cancel each other. Where soybeans are cut for seed, a considerable quantity of nitrogen and mineral plant-food elements is returned to the soil by the leaves, but too little time elapses between the maturing of the soybean crop and the sowing of the wheat crop for the supply of available nutrients to be replenished thru natural soil processes. Where the soybeans are cut for hay, there is little return of plant-food nutrients by the plant residues, but there is considerable time in which the soil nutrients may be built up.

In experiments at the Virginia Agricultural Experiment Station, Wolfe and Kipps[11*] made similar observations and obtained similar results—a yield of 19.42 bushels of wheat an acre after soybeans cut for seed and 19.52 bushels after soybeans cut for hay. The increase resulting from phosphate fertilization was approximately 2 bushels an acre. At the Ohio Station[3*] on the other hand, wheat yields have been 5.5 bushels an acre larger after soybeans cut for hay than after soybeans cut for seed.

Nitrogen not so likely to be limiting factor. Naturally the question has arisen whether the low yields of wheat following soybeans may not be due to a deficiency of available nitrogen. On soils where total nitrogen is particularly low, the lack of available nitrogen may be a factor to consider in the low yields of wheat following soybeans. At the Illinois Station, however, where wheat is grown following wheat, oats, and soybeans, a deficiency of phosphorus is of much greater importance than a deficiency of nitrogen in limiting the yields of wheat after soybeans. In fact, where wheat after wheat yielded 10 bushels more per acre than wheat after soybeans, the nitrate-nitrogen level was consistently lower, indicating that, in this case at least, nitrogen was not the factor limiting production.

Potash may be limiting factor. A soybean crop requires more potassium than a corn crop of corresponding size (page 555), and consequently one might expect that wheat following soybeans would respond favorably to fertilization with potash salts. In experiments by the Illinois Station, however, potash used alone has seldom increased the yield of wheat, but when used in addition to phosphate it has frequently given increased yields on soils deficient in available potassium.

WINTER BARLEY AFTER SOYBEANS

Winter barley may be used satisfactorily after soybeans in the southern third of Illinois. Besides reducing soil erosion, barley is an acceptable feed grain and an effective nurse crop for clover seedings.

Altho experimental data are meager, they indicate that winter barley following soybeans will respond favorably to phosphate fertilization.

SPRING-SOWN CROPS DO WELL AFTER SOYBEANS

Where erosion is controlled, crops planted in the spring on soil where soybeans were grown the preceding year do well, because, in addition to the favorable physical condition of the soil, the lapse of several months between the harvesting of the beans and the planting of the next crop gives time for the chemical and biological processes of the soil to restore the supply of available plant nutrients which was depleted by the soybeans.

TABLE 7.—AVERAGE YIELDS OF CORN, SOYBEANS, OATS, AND WHEAT THE FIRST YEAR AFTER SOYBEANS AND VARIOUS OTHER CROPS. FIFTEEN YEARS, 1922-1936
(Data from Indiana Agricultural Experiment Station[10*])

Preceding crop	Acre-yields			
	Corn	Soybeans	Oats	Wheat
	bu.	*bu.*	*bu.*	*bu.*
Soybeans	50.4	22.7	52.8	26.1
Corn	48.4	23.8	48.3	22.9
Oats	49.4	24.0	42.7	21.6
Wheat	48.6	22.6	43.8	20.0
Clover	57.9	24.0	53.9	31.9
Timothy	49.4	22.9	41.3	21.6

In crop-succession studies at the Indiana Agricultural Experiment Station[10*] over a 15-year period, the yields of corn and oats following soybeans have been second only to the yields following clover (Table 7). Corn yielded 50.4 bushels an acre after soybeans, and 57.9 bushels after clover. Oats yielded only 1.1 bushels an acre less after soybeans than after clover, and 10 bushels more after soybeans than after oats.

SUMMARY AND CONCLUSIONS

It is true of soybeans, as of most other crops, that their effect on the soil depends largely on the way they are handled. If soybeans are to be fitted most usefully into Illinois cropping systems, the crop must be handled in such a way as to contribute to soil conservation and not to soil depletion.

Erosion Problems.—Soybeans on rolling land present serious erosion-control problems. If they are planted in cultivated rows up and down the slope they, like corn, contribute to erosion. Where they are drilled solid up and down the slope, erosion losses are usually reduced about half. But the best control of erosion where soybeans are planted is obtained by drilling them solid on the contour, and following them with a winter cover crop of small grain also drilled on the contour.

Because of the difficulty of controlling weeds where soybeans are seeded solid, special care should be taken to kill as many weeds as possible before and shortly after seeding. And because present high-yielding varieties of soybeans mature rather late for seeding wheat after them, the introduction of a high-yielding, early-maturing variety which could be harvested early enough, even in unfavorable years, for wheat to be seeded afterward at the normal time, would be an important contribution toward solving the problem of soil erosion in connection with growing soybeans.

Nitrogen Considerations.—The effect of soybeans on the nitrogen content of the soil depends largely upon the use of the crop. Unless part of the tops of the soybean plant is returned in some form to the soil, nitrogen will be depleted. This is true even tho well-nodulated plants may obtain about two-thirds of their nitrogen from the air.

Combining the beans and leaving the straw on the land may cause a slight increase in the nitrogen content of the soil if the added nitrogen is not lost by leaching before it can be used by the following crop.

Used as a green manure, soybeans supply organic matter containing from 60 to 100 pounds of nitrogen an acre; but the relatively high cost of such green manure is a drawback to using soybeans for such purposes except under some special conditions.

Soybeans should be considered primarily as a cash or feed crop; and other legumes, such as sweet clover, red clover, and alfalfa, should be used for soil-improvement purposes.

Soil Minerals.—On many soils that are not in a high state of productivity, soybeans can utilize nutrient elements that are not accessible to many other crops. It is important, therefore, to return these mineral elements to the soil by fertilization if productivity at a satisfactory level is to be maintained.

Use of Winter Grain Crop.—The seeding of winter grain after the soybean crop is harvested may be expected to lessen the erosion on rolling land and to reduce leaching. The grain crop should be seeded on the contour on rolling land, and on most soils a phosphate fertilizer should be applied. The reason for adding the phosphate is that the soybeans draw heavily on the available supply of minerals so late in the fall that too little time elapses before the seeding of winter grain for natural soil processes to restore the supply of available nutrients, particularly of phosphorus. The fertilizer, by increasing the growth of the winter grain, not only improves the yield but also helps to give better protection against erosion.

Spring-Planted Crops.—On land not subject to serious erosion, the spring-planted crops, corn and oats, generally do better following soybeans than fall-seeded crops do where no fertilizer is applied. The reason for this is that during the considerable period between harvesting the soybeans in the fall and planting a crop in the spring, physical, chemical, and biological forces have time to replenish the supply of available soil nutrients.

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